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Document 20.3
LLNL Radiological Safety Program for Radiation-Generating Devices

(Formerly H&SM S33.47)

Recommended for approval by the ES&H Working Group

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20.3

LLNL Radiological Safety Program for Radiation-Generating Devices*

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LLNL Radiological Safety Program for Radiation-Generating Devices

1.0 Introduction

A radiation-generating device (RGD) is a device that generates ionizing radiation either incidentally or intentionally. The Department of Energy's (DOE's) rule on occupational radiation protection (10 CFR 835, hereafter referred to as the "Rule") requires specific controls for work with RGDs. This document contains requirements and best management practices that pertain specifically to RGDs. The Rule requirements and LLNL policies are presented as "shall" statements, and LLNL's best management practices are presented as "should" statements. Appendix A contains the definitions of "shall," "should," and other terms used in this document. Appendix B contains a tabular summary of the RGD radiological safety program requirements. The RGD flow diagram to determine program requirements is shown in Figure 1.

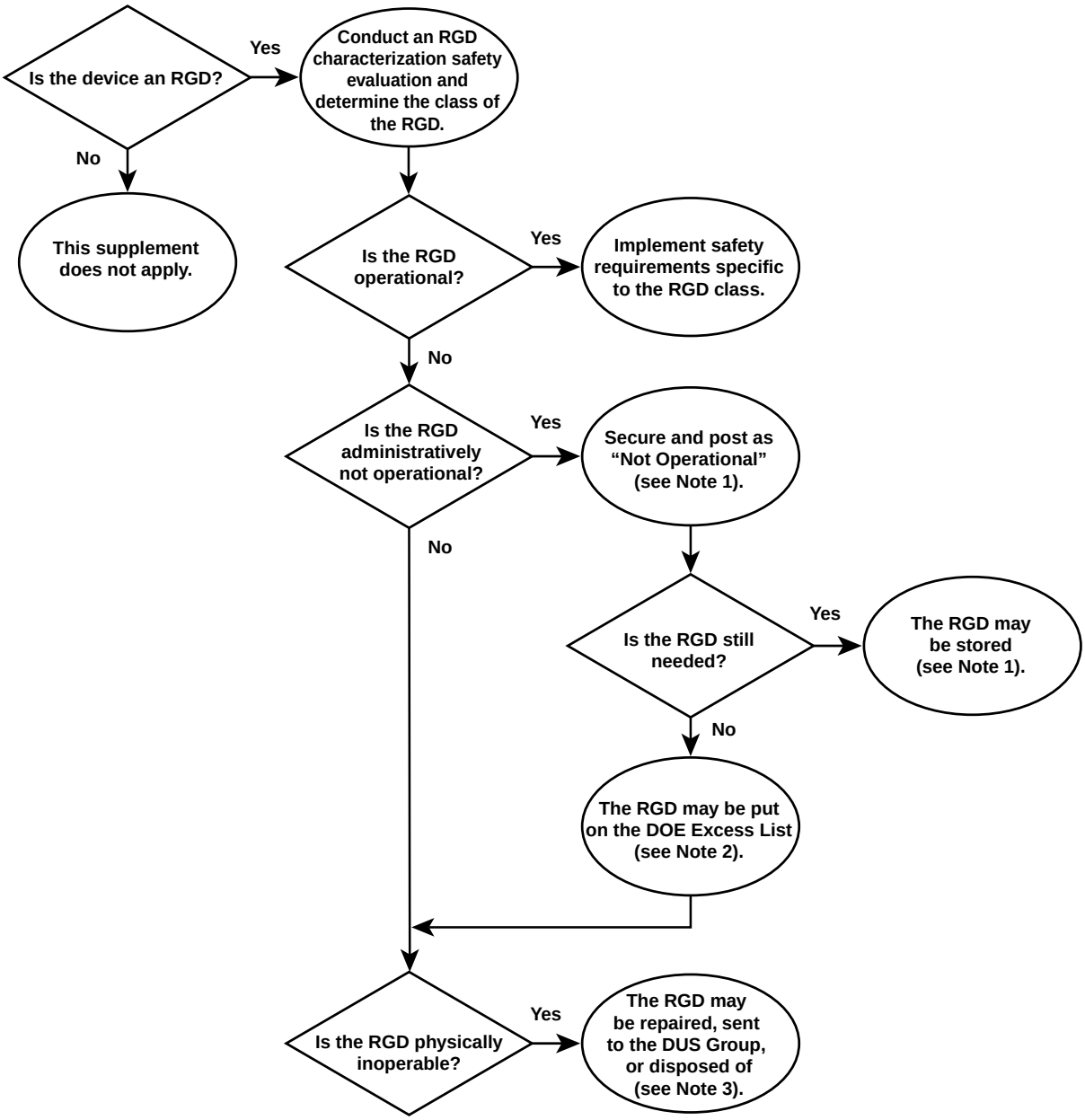
When implemented in conjunction with Document 20.1, "Occupational Radiation Protection," in the *Environment, Safety, and Health (ES&H) Manual,* this document provides a basic level of radiation protection. Deviations from the requirements of this document shall be reviewed by the ES&H Team health physicist and documented in a facility or operational safety plan. They also shall be consistent with LLNL's Radiation Protection Program (RPP) and the as low as reasonably achievable (ALARA) process described in Document 20.4, "LLNL Occupational Radiation Protection ALARA Program," in the *ES&H Manual*.

This document does not apply to medical x-ray devices (i.e., those used by the Health Services Department) and sealed radioactive sources, including those used for radiography. Medical x-ray devices used for diagnostic purposes shall comply with safety requirements specified by the Food and Drug Administration. Safety requirements for the use and storage of sealed radioactive sources are specified in Document 20.2, "LLNL Radiological Safety Program for Radioactive Materials," in the *ES&H Manual*. Other exemptions are listed in Section 3.1 of this document.

2.0 Hazards

RGDs are capable of producing extremely high radiation doses in very short periods of time. Significant overexposures to the eyes, extremities, or whole body could result if adequate engineered and administrative controls are not in place. In addition, some RGDs (e.g., high-energy electron accelerators and low-energy deuteron accelerators) are capable of activating air and materials in the accelerator enclosure. To ensure that personnel radiation doses are kept ALARA, and to ensure the proper management of activated materials, individuals who work with RGDs shall adhere to the requirements

and controls specified in Sections 3.0 and 4.0 of this document. The program or the ES&H Team health physicist may specify additional or more specific controls, as necessary.



Note 1: An annual inventory is required, but a radiation survey is NOT required.
Note 2: Complete an Equipment/Property Release Form and obtain the ES&H Team health physicist's signature.
Note 3: Notify the ES&H Team health physicist.

Figure 1. Program requirements for RGDs.

3.0 Administrative Controls

3.1 General Information

The following devices are classified as RGDs:

- **Devices that produce ionizing radiation incidentally.** These may include electron microscopes, high-voltage electron guns, electron arc-welding machines, evacuated high-voltage electronic devices, electron beam devices with energies >5 kV, and certain focused high-power lasers (i.e., those where the intensity (W/cm^2) times the wavelength^2 (μm^2) exceeds 10^{18}. Ultra-intense laser interaction with solid materials shall be evaluated on a case-by-case basis since it can lead to the production of energetic electrons (up to 100 MeV), high-intensity bremsstrahlung, charged particles, particularly energetic protons, and photo- and proton-induced neutrons.
- **Devices that produce ionizing radiation intentionally**. These may include x–ray diffraction and fluorescence analysis systems, flash x-ray machines, cabinet x-ray machines, industrial radiography equipment, ultra-intense lasers, and particle accelerators.

The following devices are exempt from classification as RGDs:

- Unmodified commercially available incidental RGDs whose potential across the terminals is ≤15 kV and that produce no significant radiation fields above background when measured at 5 cm (2 in.) from the device surface (or at the closest accessible surface) and when operated at the maximum approved operating parameters. Examples of devices that may fit into this category are high-voltage switches, planar triodes, and power supplies containing various types of thermionic valves installed in shielded cabinets or racks, mass spectrometers, vacuum switches, and spark-gap devices. The health physicist should evaluate devices to determine if they fit into this category.
- Commercially available electronic components such as cathode-ray tubes (i.e., computer monitors and televisions).

The controls for an RGD are dependent on its operational status, which may be any of the following:

- **Operational**—Device is functionally and administratively operational.
- **Not Operational**—Device is either physically or administratively not operational.

- **Transferred, Excessed, or Salvaged**—Device has been removed from LLNL, has been excessed, or has been partially or fully disassembled such that it cannot be operated without major repair by a qualified technician.

3.2 Design Criteria

General design criteria and requirements for facility and equipment design reviews are contained in Document 20.4. These design criteria apply to both the enclosure and any viewing or access ports.

All diagnostic and utility penetrations (e.g., electrical, cooling water, or optical systems) shall be adequately shielded to meet the dose criteria. Leaded glass used to shield viewing ports shall be visually distinct (e.g., mounted with colored brackets) to minimize the possibility of it being replaced with ordinary glass. Viewing ports that are directly in line with the x-ray source shall be made an integral part of the vacuum tank so that high voltage and vacuum cannot be achieved without the proper shielding in place.

3.3 Written Authorizations and Safety Plans

The following activities have been determined to be at a Work Authorization Level (WAL) B and require an Integration Work Sheet (IWS)

- To control entry into and to perform work within radiological areas (e.g., Radiation Areas and High Radiation Areas).
- To operate Class I, II, III, or IV RGDs.
- To purposely break an x-ray tube (e.g., to render it nonfunctional for the purposes of disposal). (See Section 3.5.5.)
- For maintenance and repair operations (including interlock bypass operations) that are not covered under the facility or operational safety plan.

  Note: Interlock bypass operations necessitated for maintenance and repair shall be approved by the Responsible Individual with the concurrence of the ES&H Team health physicist.

A safety plan (IWS/SP or FSP) is required for the following operations. Refer to ES&H Manual Document 2.2.

- For safety-interlock bypass operations (except as noted for maintenance and repair).
- For open beam operations.

- For field radiography.
- To document deviations from the requirements in this document.
- To operate Class II and III RGDs unless the authorizing individual, with the concurrence of the ES&H Team health physicist, determines that a safety plan is not necessary.
- To operate a Class IV RGD.

3.4 Posting and Labeling

General posting requirements are contained in Document 20.1; specific guidance is contained in the *Radiation Safety Sign Manual*. Posting requirements that pertain exclusively to RGDs are presented in this section. (**Note**: Posting requirements may be waived for periods of less than 8 continuous hours when the area is placed under the continuous observation and control of an individual knowledgeable of and empowered to implement required access and exposure control measures.)

3.4.1 Radiologically Controlled Areas

A radiologically controlled area is any area where access is managed to protect individuals from exposure to radiation. Access points to areas that are not radiological areas but contain Class II, III, or IV RGDs shall be posted with either a CAUTION X–Ray Area or a CAUTION Accelerator Area sign. (**Note**: Areas that contain neutron-generating RGDs should be posted with the CAUTION X–Ray Area sign.)

3.4.2 Radiological Areas

Each access point to a Radiological Area (e.g., a Radiation Area, High Radiation Area, Very High Radiation Area, and Contamination Area) shall be conspicuously and appropriately posted. The definitions of these terms are contained in Appendix A.

Note: High-energy accelerators can activate dust and other materials in the area and potentially create a Contamination Area. In addition, radioactive materials could be associated with RGDs that are used to analyze radioactive samples or that have built-in radioactive sources.

3.4.3 Radiation-Generating Devices

RGDs shall be posted and labeled as follows:

- Each device shall be labeled with a unique RGD number provided by the RGD safety officer. If more than one head is used with a controller, each head shall have a unique head or tube number.

  Note: RGDs that have been specifically evaluated and determined to be exempt should be labeled with an "Exempt RGD" sticker, which is available from the RGD safety officer. This nonmandatory label helps avoid doubt as to whether or not the RGD was initially characterized.

- A CAUTION Radiation-Generating Device—Approved Operating Parameters label shall be posted on the device console or other appropriate location.

- A CAUTION Radiation-Generating Device label shall be posted close to the port on each tube housing, if feasible. (Class I devices do not require this label.)

- A Date Surveyed and Next Survey Due sticker should be attached to the device console or other appropriate location. (Stickers are not necessary on devices that are waived from periodic RGD radiological safety surveys.)

3.5 Managing RGDs

3.5.1 Procuring RGDs

The Hazards Control Department's RPP subject-matter expert (RPP-SME) or the RGD safety officer shall concur with all purchase orders for new RGDs, the acquisition of RGDs from other institutions, and the construction of RGDs onsite.

3.5.2 Transferring or Moving RGDs

To ensure compliance with applicable radiation-protection regulations, the operator or Responsible Individual shall

- Notify the ES&H Team health physicist or the health and safety technician prior to physically moving an RGD or administratively transferring an RGD to an onsite or offsite location or to the DOE Excess List.

- Complete the Equipment/Property Release Form for planned transfers of intact RGDs and x-ray tubes to non-LLNL individuals or institutions. The ES&H Team health physicist shall sign the completed form. (**Note**: RGDs

may only be transferred to appropriately authorized individuals or institutions, as determined by the RGD safety officer.)

- Ensure the RGD is labeled as capable of producing x-rays.

3.5.3 Controlling RGDs

When not in use, Class II, III, and IV RGDs shall be stored in a manner that prevents unintended and unauthorized operation or tampering (e.g., in a locked enclosure or room).

RGDs that are no longer needed but are still capable of producing x-rays shall be posted as "Not Operational" and may be left in place or sent to equipment storage. The RGD label indicating that the device generates x-rays shall remain on the device.

3.5.4 Inventorying RGDs

Class I and II RGDs shall be inventoried at least annually. Class III and IV RGDs shall be inventoried at least semiannually. If deemed appropriate by the ES&H Team health physicist, Class I RGDs may be inventoried by verbally contacting the device operator. The RGD safety officer prompts the ES&H Team when the inventory is due; the ES&H Team notifies the RGD safety officer upon completion of the inventory. The inventory is typically conducted in conjunction with the radiological safety survey.

3.5.5 Disposing of RGDs

Unwanted but operational RGDs may be included on the DOE Excess List, which is managed by the Donation, Utilization, and Sales (DUS) Group. RGDs that are on the DOE Excess List:

- May be stored either in the programmatic area or at DUS.
- Will be made available to other DOE contractors that are authorized to have them.

If the RGD is stored at DUS beyond a certain period of time (usually several months), DUS asks the Responsible Individual to do one of the following:

- Return the RGD to the programmatic area.
- Remove the tube from the RGD.
- Render the RGD nonfunctional (i.e., broken beyond repair).

Only RGDs that have been rendered nonfunctional may be sent for metal recycling or disposed of in a municipal landfill.

Tubes removed from an RGD may be:

- Returned to the manufacturer. (This is the preferable disposal method.)
- Stored by the Responsible Individual for future use. (The tube shall remain labeled as an RGD and shall continue to be inventoried.)
- Disposed of as hazardous waste or in the municipal landfill, as appropriate. Disposal as hazardous waste is usually required because most tubes contain beryllium. Contact the ES&H Team Environmental Analyst to determine the appropriate disposal method.
- Rendered nonfunctional and disposed of as specified above. Great care is needed when rendering a tube nonfunctional because tubes typically contain hazardous materials (e.g., beryllium) and are under vacuum. An IWS is required for this operation.

Decommissioning or dismantling of accelerators or other large devices shall be handled on a case-by-case basis.

3.6 RGD Characterization

RGDs, including all x-ray ports and tubes, shall have an initial characterization. The evaluation shall be completed jointly by the operator and the ES&H Team health physicist before routine use of a new device and repeated whenever the maximum operating parameters of the RGD change.

If the RGD is physically modified following the original characterization, it shall be recharacterized to validate that the safety features have not been compromised. Modification includes adding or removing beam ports, changing tubes, and modifying shielding or interlocks. An RGD's characterization shall be updated if the RGD is moved to another room or facility.

The RGD characterization is conducted to assess:

- The capabilities of the device.
- The measured radiation intensity produced by the maximum approved operating parameters.
- The safety features associated with the device.
- Associated operating procedures.
- Potential accidental doses resulting from a credible accident scenario (i.e., failure to follow procedures, failure of a single component, or disassembly of the device or the housing it resides in).

Characterizations shall be documented on the RGD Characterization Form, which can be obtained from the ES&H Team. A copy of the completed form shall be kept in the RGD logbook (for Class II, III, and IV devices) or with the device operator, and a copy shall be sent to the RGD safety officer for concurrence and long-term record storage.

3.7 Classifying RGDs

The ES&H Team health physicist shall classify RGDs into one of four categories (Class I, II, III, or IV) based on the results of the RGD characterization and the radiation safety evaluation. Safety requirements increase as the class number increases. If additional safety requirements are needed to assure safe operations, the health physicist may classify the device into a higher category.

Table 1 shows the maximum potential dose to the extremity, eye, or whole body associated with each class of RGD. The health physicist shall use the most restrictive dose to determine an RGD's class. For example, if an RGD is capable of producing 100 rem to an extremity and 50 rem to the eye in a reasonable accidental exposure, but is incapable of producing a whole-body dose, the RGD is a Class III device. If the RGD is capable of producing >15 rem to the whole body, it is a Class IV device regardless of the potential for extremity or eye exposure.

Table 1. Maximum potential accidental dose used to classify RGDs at LLNL.

Organ	Maximum dose (rem)			
	Class I	**Class II**	**Class III**	**Class IV**
Extremity	<0.1	150	>150	—
Eye	<0.1	45	>45	—
Whole body	<0.1	15	—	>15

3.7.1 Class I Devices

These devices are incapable of reasonably producing an accidental dose >0.1 rem per incident to either a localized area of the body (e.g., an eye or a finger) or to the whole body. Examples of devices that may fit into this class are vacuum-plating units, electron microscopes, high-voltage rectifiers, electron-beam coaters, and certified cabinet x-ray systems.

Class I devices are designed by the manufacturer to be inherently safe. These devices include shielding and design features that permit operation without requiring significant occupancy controls or personnel in attendance.

3.7.2 Class II and III Devices

Class II devices could reasonably produce accidental doses up to three times the occupational annual dose limit (see Table 1). Examples of devices that may fit into this class are low-intensity flash x-ray devices, radiographic x-ray devices, e-beam devices, and diffraction or fluorescence devices.

Class III devices could reasonably produce an accidental extremity or eye dose in excess of three times the occupational annual dose limit (see Table 1) and may be capable of producing severe biological effects to localized areas of the body. Class III devices are unlikely to produce lethal doses of radiation due to the limited area of exposure. Examples of devices that may fit into this class are flash x-ray devices, radiographic x-ray devices, e-beam devices, and diffraction or fluorescence devices.

The primary beam of Class II or III RGDs may be inaccessible without disassembling the unit, enclosed during normal operations, or may be in an open-beam configuration. A secondary beam may be generated by diffraction or fluorescence and may be inaccessible, enclosed, or in an open-beam configuration.

3.7.3 Class IV Devices

Class IV devices can reasonably produce more than three times the occupational annual dose limit to the whole body (see Table 1) and may be capable of producing lethal doses of radiation. Examples of devices that may fit into this class include radiographic devices and particle accelerators. High-energy accelerators identified in Section 3.11 shall be classified as Class IV RGDs.

3.8 Radiological Safety Surveys

The Hazards Control Department and the device operator shall conduct a radiological safety survey at the frequency listed below, or sooner if the RGD is modified or the location or maximum approved operating parameters are changed.

- Class I and II RGDs shall be evaluated at least annually. The ES&H Team health physicist may waive the radiological safety survey for Class I devices if the associated risks are minimal and the waiver is noted on the Characterization/Radiation Safety Evaluation Form.
- Class III and IV RGDs shall be evaluated at least semiannually.

A radiological safety survey includes:

- A review of administrative information (e.g., manufacturer and model number, device location, Responsible Individual, approved operators, operational status of the RGD).
- A review of operating parameters.
- A review of area and RGD postings.
- A review of RGD warning indicators.
- Interlock testing (if feasible).
- A radiation survey of potentially occupied areas, except as noted below. The survey shall be conducted with the device operated at the maximum approved operating parameters. A radiation survey is not required as part of the safety survey for field radiography RGDs. The radiation survey for field radiography RGDs shall be conducted at the time and in the location of use.

Survey results shall be documented on the Radiological Safety Survey Form, which can be obtained from the ES&H Team. The completed form shall be:

- Legibly signed or, if the names are typed, initialed by the individuals conducting the survey (who, typically, are the user and the ES&H Team health and safety technician).
- Reviewed and initialed by the ES&H Team health physicist (or the RGD safety officer).
- Filed with the RGD operator (in the logbook, preferably).
- Copied and forwarded to the RGD safety officer for permanent recordkeeping.

3.9 Monitoring the Individual

External dose monitoring requirements are specified in Document 20.1. The following information is specific to RGD operators and others working in close proximity to RGDs. The ES&H Team health physicist may increase the basic monitoring requirements. If multiple monitoring requirements apply (e.g., due to operations in multiple facilities), the most conservative shall be implemented.

3.9.1 Class I RGDs

Whole-body dosimeters should be issued and exchanged at least quarterly unless the ES&H Team health physicist specifies otherwise, in writing [normally in the RGD logbook, Health Physics Discipline Action Plan (HP-DAP), or other safety document].

3.9.2 Class II, III, and IV RGDs

- Whole-body dosimeters should be issued and exchanged monthly, unless otherwise specified by the ES&H Team health physicist in the RGD logbook, HP-DAP, or safety plans.
- Extremity dosimeters (e.g., finger rings or wrist dosimeters) shall be worn if specified by the ES&H Team health physicist in the safety plan, RGD logbook, or HP-DAP. Specific operations that might warrant the use of extremity dosimeters include
  - — Sample changing.
  - — Target changing.
  - — Interlock bypass operations.
  - — Beam alignment.
  - — Open-beam operations.

3.9.3 Class IV RGDs

In addition to the above, the following requirements apply to Class IV RGDs:

- Neutron dosimeters may be required for work around some accelerators (e.g., if the individual is likely to receive a whole-body neutron dose exceeding 0.05 rem/y). Individuals required to wear neutron dosimeters should be identified in the RGD logbook or in the HP-DAP.
- A supplemental whole-body dosimeter (or other means capable of providing an immediate estimate of the individual's integrated deep dose equivalent during the entry) shall be worn during access to High Radiation Areas. Where a supplemental dosimeter is impractical or ineffective (e.g., when monitoring doses from neutron radiation), other means, such as knowledge of the area exposure rate and tracking of individual access times, may be used to provide immediate indication of an individual's dose. Supplemental whole-body dosimeter readings shall be recorded in the RGD logbook.

3.10 Documentation

The operator of each Class I device should maintain copies of the current RGD Characterization/Radiation Safety Evaluation Form and the most recent Radiological Safety Survey Form. A formal logbook is not required.

Each Class II, III, and IV RGD shall have a logbook, which should be kept near the control console. The RGD logbook should contain the following documents (or reference where they can be easily found):

- A current RGD Characterization/Radiation Safety Evaluation Form.
- Any controls required for RGD operation (e.g., required use of extremity or neutron dosimeters).
- A current Radiological Safety Survey Form.
- Written interlock test procedures (see Section 4.1.1).
- A copy of the operational safety plan, if required.
- Maintenance records.
- A list of approved operators.
- Pertinent RGD correspondence.

In addition to the logbook, each Class IV device shall

- Identify the Responsible Individual for the RGD.
- Have a use log indicating the date, time, operator, and a description of the RGD's use. Alternative documentation methods may be outlined in the safety plan.

RGD records shall be retained until DOE authorizes their disposition. Logbooks may be retained by the facility (as specified in Appendix F of Document 20.1) or sent to the RGD safety officer for long-term storage.

3.11 Additional Requirements for High-Energy Accelerators

The requirements in this section apply to accelerator operations that create either of the following (see Table 2):

- A "High Radiation Area" (after accelerator operations) as a result of activation of structures or components.
- An "Airborne Radioactivity Area" (during or after accelerator operations) as a result of activation of air.

Note: Until late 2001, LLNL-designated accelerator facilities included all accelerators capable of accelerating particles to ≥10 MeV. Contact the Hazard Control Department's Authorization Basis Section for guidance in declassifying LLNL-designated accelerator facilities that do not meet the above specifications.

Table 2. High-energy accelerators capable of creating a High Radiation Area or an Airborne Radioactivity Area as a result of activation.

Accelerator	RGD Terminal Voltage (MV)	Located in Building
LINAC		194
LINAC		851

3.11.1 Safety Assessment Document

Each accelerator shall have (or be part of) a Safety Assessment Document (SAD) that is current and consistent with the administrative controls and physical configuration of the facility and major safety equipment. The SAD may be incorporated into other equivalent documents (e.g., Safety Analysis Reports, Safety Analysis Documents). It may be prepared as a single document addressing the hazards of the entire accelerator facility or as separate SADs for discrete modules of the facility (e.g., injectors, targets, experiments, experimental halls, and other types of modules). For additional information on writing a SAD, see Document 3.1, "Safety Analysis Program," in the *ES&H Manual*.

The SAD shall contain the following:

- Hazards from both normal operations and credible accidents in the facility and associated onsite and offsite impacts to workers, the public, and the environment.
- Sufficient descriptive information and analytical results pertaining to specific hazards and risks identified during the safety analysis process to provide an understanding of the risks presented by the proposed operations.
- A detailed description of engineered controls (e.g., interlocks and physical barriers) and administrative controls (e.g., training) implemented to eliminate, control, or mitigate risks associated with the operation.
- A description of (or a reference to) the facility's function, location, and management organization, as well as details of major facility components and their operation.
- The set of physical and administrative bounding conditions for safe operations, based on the safety analysis documented in the SAD. These bounding conditions are known as the Accelerator Safety Envelope (ASE).

Any activity violating the ASE shall be terminated immediately, pending notification of the DOE.

3.11.2 Unreviewed Safety Issues

Activities that involve an Unreviewed Safety Issue (USI) (i.e., an activity that is not covered by the existing safety basis document or that involves equipment important to safety for which a safety analysis has not been performed) shall not be performed until it is determined if significant safety consequences could result from either an accident or malfunction of equipment. Activities involving an identified USI shall not commence without written approval from DOE. Document 3.1 provides requirements for preparing the paperwork associated with an USI.

3.11.3 Accelerator Readiness Reviews

Accelerator Readiness Reviews shall be performed prior to approval of commissioning and routine operation, and as directed by the cognizant DOE secretarial officer or a field element manager. See the prestart requirements in Document 2.2.

3.12 Training

Document 20.1 contains the following:

- Institutional training requirements for access to areas posted with the radiation trefoil symbol and for radiological work.
- Local training requirements that may be required for work in specific facilities or organizations.
- Retraining requirements.
- Provisions for use of escorts in lieu of training.

Training that pertains specifically to RGDs is listed below.

3.12.1 Class I RGDs

A Hazard Information Sheet (available from the RGD safety officer) shall be conspicuously posted next to the RGD or included in the safety plan. All individuals using or working on the RGD shall read this sheet. Classroom training is not required.

3.12.2 Class II, III, and IV RGDs

Individuals who operate or work in close proximity to accelerators, e-beam devices, and other Class II, III, or IV RGDs shall complete all applicable courses listed in Livermore Training Records and Information Network (LTRAIN). Retraining is required every 24 months.

The following courses (or approved alternates) are required:

- Individuals working with or in close proximity to operating accelerators (including LINACs used for radiography) shall complete course HS6911, Radiological Worker Training for Accelerator Facilities.
- Individuals working with other types of operating RGDs (including e-beam devices) shall complete course HS6070, Safety and the X-Ray Machine.

4.0 Engineered and Operational Controls

Engineered and operational controls for Class I, II, III, and IV RGDs are presented in this section and summarized in Appendix B. Controls that apply to all classes of RGDs are listed under the primary headings (e.g., Sections 4.1 and 4.2); controls that apply to specific classes of RGD are listed under subheadings (e.g., Sections 4.1.1 and 4.1.2). Additional controls may be identified in Hazard Assessment Reports (HAR) and Safety Analysis Documents (SAD).

These controls are for fixed facilities and may not be appropriate for short-term or temporary operations (e.g., field radiography). Alternate controls that provide a commensurate level of safety may be used if explicitly stated in an approved safety plan. Additional information is provided in Document 12.1, "Access Control, Safety Signs, Safety Interlocks, and Alarm Systems," in the *ES&H Manual*.

The controls specified in this section may not be appropriate for every type of RGD used at LLNL. Controls that are not appropriate should not be implemented. The ES&H Team health physicist and the RGD safety officer shall concur with any decision as to which controls are not appropriate and not to be implemented. Controls not to be implemented shall be documented in the RGD characterization, safety plan, or other safety document.

4.1 Interlocks

This section applies to interlocks that prevent exposure to radiation. Controls for interlocks that are installed for other purposes (e.g., to prevent access to exposed high voltage) are addressed in Document 12.1.

- Interlocks installed by the manufacturer shall not be disabled or modified without the approval of the authorizing individual, with the concurrence of the ES&H Team health physicist.
- Use of interlock bypass features or devices (e.g., jumpers or key switches), including those installed by the manufacturer, shall be documented in a safety plan.
- The interlock bypass key(s) shall be removed and secured unless an authorized bypass operation is in process.
- Interlocks shall be tested at least on the same frequency as that specified for the radiological safety survey.

4.1.1 Class II, III, and IV RGDs

- Fail-safe interlocks shall be installed on protective enclosures needed to prevent access during normal operation.
- Written interlock test procedures shall be established and used for each interlock system. The test procedure shall identify the number of interlocks to be tested, how the test is to be performed, and the pass/fail criteria. The Responsible Individual shall ensure the test procedure is adequate for the equipment and operation.
- Interlock test results shall be documented in the RGD logbook.
- Enclosures to flash x-ray machines shall be interlocked to prevent entry when the high-voltage system is charged (or while it is being charged). When the interlock is opened, the high-voltage shall be automatically grounded.
- Rooms or other facilities used as x-ray enclosures shall have an emergency shutdown switch if a person could, in a reasonable accident scenario, become trapped in the room when the x-ray beam is on.
- If an interlock malfunctions, it shall be repaired before the machine may be operated.

4.1.2 Class IV RGDs

In addition to the above, the following requirements apply to Class IV RGDs.

- The control console shall be interlocked so that turning the key to the off/safe position will interrupt the high-voltage supply.
- All interlock bypasses shall be designed to assure that they are only temporary. An interlock bypass condition shall be immediately recognizable at both the control console and at the interlock location. The time the bypass

is turned on and off as well as the reason for the bypass shall be entered into the RGD logbook.

- Access gates or doors to exclusion areas shall be interlocked so that when the gates or doors are opened, the high-voltage supply to the device is interrupted. Redundant interlock chains or pairs of interlock switches shall be installed. Document 12.1 provides more details.
- Hazard-safe (run-safe) switches or boxes capable of interrupting the high-voltage supply shall be located near entrances to and in exclusion areas where work could be performed. Upon entering an area equipped with hazard-safe switches, personnel shall set at least one switch to the safe position, unless this occurs automatically.
- Before starting up a Class IV device, the operator shall perform a rigorous sweep of all potential High Radiation Areas and Very High Radiation Areas. Key-lock watchman stations (or run-safe boxes) shall be placed in strategic positions within the exclusion area to guarantee that all locations within the area have been inspected prior to operation. Exceptions to requiring key-watchman stations can be made if the exclusion area is small and visibility is unimpeded. Key-lock watchman stations shall have the following features:
  - — RGD operation shall be impossible unless all watchman stations are reset with either the master key or a key that is always on the master ring.
  - — If an individual could enter the area during the inspection without being seen, a key-lock watchman station with a timer shall be installed such that the inspection shall be completed within a specified time period.
  - — Opening any entry to an area shall necessitate manually resetting all watchman stations in that area.
- Personnel safety interlocks shall not be capable of being reset from the operator's console (i.e., RGD operators shall go to the tripped personnel safety interlock to reset it). The master key shall be necessary for resetting an exclusion-area door interlock. Interlocks shall not be used to turn off an RGD, except in an emergency.

4.1.3 Field Radiography

The Rule requires that radiation exposure in controlled areas be kept ALARA through physical design features and administrative control and that administrative controls be employed only as supplemental methods to control radiation exposure. For an activity in which use of physical design features is demonstrated to be impractical, administrative controls shall be used to maintain radiation exposures ALARA. Administrative controls shall be documented in a safety plan. If a generic field radiography safety plan (i.e., a safety plan that allows for future field

radiography in general) is written, an IWS (signed by the management in the facility or area where the operation is to occur) should be used to provide the site-specific information and controls.

A subcontractor's company safety plan may be used in place of an LLNL safety plan if deemed acceptable by the Responsible Individual and the ES&H Team health physicist. In such cases, the form "Radiation Work Permit for Subcontractors" (available from your ES&H Team health physicist) shall be completed.

The term "field radiography" originally referred to radiography conducted in locations without physical design features to provide shielding or access controls. Now, the term more generally refers to radiography conducted in an area or facility that does not have the requisite engineered controls. Field radiography is appropriate when it is impractical, impossible, or unsafe to transport an item to a radiographic facility (e.g., when conducting radiography at construction sites or diagnostics on devices, items, or structures that cannot reasonably or safely be moved).

Programs may wish to conduct field radiography in a facility where it is possible, but not necessarily practical, to implement engineered controls. Deciding whether it is practical to implement engineered controls is somewhat subjective; however, as a rule of thumb, engineered controls should be implemented for a radiographic operation that is expected to exceed either of the following:

- A span of 2 weeks.
- A frequency of six times a year.

The ES&H Team health physicist, the RGD safety officer, and the authorizing individual shall concur with any field radiography operation that is expected to exceed the above parameters.

Because field radiography is, by definition, conducted in areas that are not designed for radiographic operations, individuals not associated with the operation are often exposed to low levels of radiation. Operation shall be planned so that the dose to such unassociated individuals is kept ALARA (and, ideally, to less than 1 mrem per person). An anticipated dose in excess of 10 mrem to any unassociated individual requires the approval of the authorizing individual and the concurrence of the ES&H Team Leader. The ES&H Team Leader shall consult with the RPP-SME, prior to concurring with the approval.

4.2 Warning Indicators

Warning lights installed by the manufacturer, such as an "X-Ray On" light, shall not be modified without the concurrence of the ES&H Team health physicist. The concurrence shall be documented in the RGD logbook or in the safety plan.

4.2.1 Class II and III RGDs

- Fail-safe warning lights shall be installed near the x-ray source to indicate when x-rays are being generated or when a flash x-ray system is charged (or is being charged). E-beam devices should have a fail-safe warning light installed in close proximity to the source to indicate when the machine is on.
- A fail-safe "X-Ray On" light shall be located near the switch that energizes the x-ray tube. The light on the control console of flash x-ray machines shall indicate their charging status.
- RGDs with shutters should have fail-safe "Shutter Open" lights mounted near the shutters to indicate the machines' status.
- The "closed" and "open" shutter positions shall be easily identified for devices with a shutter or other absorber.

4.2.2 Class IV RGDs

- After completing a sweep of the exclusion area and approximately 60 seconds prior to operating a Class IV RGD, the lights shall be dimmed and an audible voice or taped announcement shall state that the device is about to be operated and personnel are to immediately turn the hazard-safe (run-safe) switch to SAFE and leave the area. It is not required to dim the lights or have a voice announcement under any of the following conditions:
  - — Open-beam operations where the operator is authorized to remain in the room during RGD operations.
  - — Temporary or short-term operations.
  - — Operations in a small exclusion area where it is not possible for a person to be present and not know the device is about to be operated.
- Entrances to High Radiation Areas and exclusion areas shall be equipped with flashing or rotating magenta lights that operate automatically whenever a Class IV device is in use.
- An audible signal shall be produced while Class IV devices are being operated. The audible signal for all Class IV devices operated within the same facility should be consistent so that personnel can immediately recognize the signal's meaning. Chimes are typically used to indicate radiation is being generated, and intermittent (i.e., pulsating) Klaxon horns are typically used to signal evacuation.

4.3 Radiation Monitoring

An appropriate portable radiation survey instrument shall be available for use during Class II, III, and IV RGD operations.

4.3.1 Class II and III RGDs

An x-ray monitor (LEA-92-1920) or x-ray safety box (LEA-83-1659-00), or equivalent fixed radiation detector with an alarm, should be installed if any of the following conditions exists:

- The primary beam is accessible.
- Shielding can be easily removed.
- Interlocks can be easily bypassed.
- The radiation safety evaluation determines that installation of a safety monitor or safety box could prevent an inadvertent exposure.

Fixed monitors are not required if the x-ray beam is accessible only for small distances and a monitor would interfere with its operation.

Note: The x-ray monitor is not effective in a pulsed radiation field.

4.3.2 Class IV RGDs

A remote area monitor (RAM) system should be installed in all potentially High Radiation Areas to alert personnel to radiation levels before entry. Each RAM should have a remote and local readout, with visible and audible alarms at both the control panel and the monitored locations. Visible alarms installed at monitored locations shall be a rotating magenta light. Each installed RAM shall be checked for radiation response and calibrated annually.

Note: Calibration of installed radiation monitoring systems is typically conducted by the Plant Engineering Alarms Crew. Programs/facilities are responsible for arranging for and assuring the completion of routine calibration of these systems. Delegation of this task to others shall be documented in the safety plan.

4.4 Shielding

The RGD, including viewing access ports and utility penetrations, shall be adequately shielded to reduce the dose to personnel operating the equipment or occupying the area adjacent to the RGD to ALARA. Shielding installed by the manufacturer shall not be modified without prior concurrence of the ES&H Team health physicist. Design criteria for facilities are contained in Document 20.4.

4.4.1 Class I RGDs

Class I RGDs should be shielded such that the dose rate is less than 0.5 mrem/h when measured at 5 cm (2 in.) from the enclosure. Class I RGDs shall be designed or shielded such that an individual is unlikely to receive either a localized or a whole-body dose exceeding 0.1 rem/y under normal or accidental conditions.

4.4.2 Class II and III RGDs

Class II and III RGDs should be shielded such that the dose rate is less than 0.5 mrem/h when measured at 30 cm (12 in.) from the enclosure. Beams with dose rates exceeding 0.1 rem/h should be fully enclosed, when feasible; all beam ports shall be covered with a radiation shield when not in use.

4.4.3 Class IV RGDs

Class IV RGDs should be shielded such that the dose rate on the outside of the enclosure is less than one-tenth the maximum annual permissible dose (i.e., <0.5 rem/y) when measured at 30 cm from the shield.

4.5 Maintenance and Repair

The following requirements apply to the maintenance or repair of RGDs:

- Program personnel shall discuss with the Responsible Individual and the ES&H Team health physicist any work that could impact the safety system on an RGD, even if an authorized factory representative is performing the work. Any work limitations associated with maintenance and repair shall be documented in a safety plan or in the RGD logbook.
- If individuals performing the work are not LLNL employees, they shall provide documentation that they are adequately trained to do the work. A letter on company letterhead indicating the person is a factory-authorized representative that is adequately trained to do the work is sufficient.
- The individual performing work shall verify the power is OFF before performing work that involves the removal of protective shielding or modification of shutters, collimators, or beam stops. The main switch, rather than the safety interlocks, shall be used to shut down the machine. Document 12.6, " LLNL Lockout/Tagout Program," in the *ES&H Manual* shall be followed.

- The RGD operator shall document all maintenance and repair of the RGD. Documentation should include what was done, by whom, the date of the work, and the follow-up radiological safety survey, if required.
- Before resuming program operations, the Hazards Control Department shall conduct a radiation survey following maintenance or repair that involves disassembly of the x-ray tube, tube housing, shutters, or shielding. If the device has been modified significantly, it shall be recharacterized by the ES&H Team health physicist or an appropriate alternate (e.g., the RGD safety officer). The Responsible Individual shall ensure this survey is conducted as required.
- When the safety device or interlock has been approved to be bypassed or is awaiting repair, the RGD enclosure should be conspicuously posted with a sign bearing the words, "CAUTION: Safety Device Not Functioning."

4.6 Access Controls

Personnel entry control shall be maintained for each radiological area. The degree of control shall be commensurate with existing and potential radiological hazards in the area.

4.6.1 Class II, III, and IV RGDs

- An appropriate portable radiation survey instrument shall be used for each initial entry into a potentially High Radiation Area (except in the case of pulsed radiation fields) and when the levels of radiation are unknown.
- A supplemental whole-body dosimeter (or other means capable of providing an immediate estimate of the individual's integrated deep-dose equivalent during the entry) shall be worn during access to High Radiation Areas.
- An individual identified by the Responsible Individual and documented in the RGD logbook shall be the first person to enter an exclusion area after device operation.
- Controls shall not prevent the rapid evacuation of personnel from a potentially High Radiation Area or Very High Radiation Area.
- The master key(s) for the control console of Class IV devices shall be the only key(s) that allows access to exclusion areas.

4.6.2 Open-Beam Operations

Following are physical or administrative controls that shall be used to control access to radiological areas:

- Radiological Areas shall be delineated and properly posted (see Section 3.4).
- Individuals shall be excluded from High Radiation Areas during RGD operation.
- If physical barriers do not preclude access to High Radiation Areas, a trained operator shall provide surveillance and prevent access.
- Additional control measures (e.g., interlocked "photoelectric eye" light beams) that prevent inadvertent or unauthorized access shall be installed at the access points to Very High Radiation Areas.
- Following RGD operation, the operator shall use an appropriate survey meter to verify that radiation is no longer being produced before any part of the body enters a potential High Radiation Area or Very High Radiation Area.

4.7 Other Controls for High-Energy Accelerators

- **Radiation Effluent Monitors**. Radiation effluent monitoring may be required if significant air, gas, or dust activation is expected as a by-product of operating a Class IV RGD. The Hazards Control Department will assist the Environmental Protection Department in determining when effluent monitoring is required and the type of monitoring to be performed.
- **Activation Products**. Class IV RGDs may cause exposed objects, tools, or shielding to become activated. Items removed from exclusion areas where such activation is likely shall be surveyed prior to release and handled appropriately. Requirements for handling radioactive materials is contained in Document 20.2.

5.0 Responsibilities

All workers and organizations shall refer to Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management" in the *ES&H Manual* for a list of general responsibilities. The responsibilities for each individual and organization who have key safety roles are specified below each title. These responsibilities are specific to RGD operations and are in addition to those identified in Document 20.1.

5.1 Authorizing Individuals

- Authorize RGD operations.
- Provide the resources for safe RGD operations.
- Ensure the conduct of safe RGD operations.
- Ensure the safety assessment documents (for accelerators) and safety plans (as required in Section 3.2) are maintained to reflect the current status of the facility and RGD operations.

5.2 Responsible Individuals (RGD Custodians)

- Contact the ES&H Team before purchasing, acquiring, building, moving, or modifying an RGD.
- Ensure that RGDs are characterized, an RGD logbook is maintained, and radiological safety surveys are conducted as specified in this document.
- Maintain mechanical and electrical schematic diagrams, manufacturer-provided instruction manuals, and operating and maintenance records.
- Ensure the interlock test procedure is adequate for the equipment and operation.
- Ensure RGD operators have completed the requisite training.
- Control the issuance of keys to key-controlled RGDs and RGD installations.
- Prevent operation of RGDs that do not have a current radiological safety survey.
- Assist in the RGD characterization.
- Provide job-specific training for RGDs.
- Prevent unauthorized use of RGDs.

5.3 Radiation Workers (RGD Operators)

- Maintain an RGD logbook for Class II, III, and IV RGDs.
- Only operate RGDs that have a current radiological safety survey.
- Use the RGD only in its approved configuration.
- Assist in the radiological safety survey.
- Terminate unsafe RGD operations and promptly notify the Responsible Individual.

5.4 Hazards Control Department

5.4.1 ES&H Team Health and Safety Technician

- Post areas and machines as specified in Section 3.4 of this document.
- Conduct radiological safety surveys in conjunction with program personnel.

5.4.2 ES&H Team Health Physicist

- Characterize the RGD in conjunction with program personnel.
- Identify appropriate controls for RGD operations.
- Review radiological safety surveys.

5.4.3 RGD Safety Officer

- Develop and maintain the RGD safety program.
- Provide radiological safety oversight of the RGD safety program.
- Maintain the RGD files.

6.0 Work Standards

10 CFR 835, "Occupational Radiation Protection."

DOE O 420.2A, *Safety of Accelerator Facilities.* [This order applies only to accelerators capable of creating an Airborne Radioactivity Area or High Radiation Area as a result of activation. Only Paragraph 3c and Paragraph 1 (a–d only) in the Contractor Requirements Document apply.]

7.0 Resources for More Information

7.1 Contacts

For additional information about working safely with RGDs, workers should contact the following:

- The Responsible Individual.
- The authorizing individual (facility/program manager).
- The ES&H Team health and safety technician.
- The ES&H Team health physicist.
- The Hazards Control Department RGD safety officer.
- The Hazards Control Department RPP-SME.
- The Hazards Control Department Radiation Safety Program Leader.

Hazards Control Department personnel can be reached through the ES&H Contact List.

7.2 Applicable Lessons Learned

The "Radiation Protection" category of the Lessons Learned Program contains information pertinent to RGDs. The Lessons Learned Program is available at the following Internet address:

http://www.llnl.gov/llnl_only/es_and_h/lessons/lessons.shtml

7.3 Other Sources

For additional information about topics discussed in this document, refer to the*ES&H Manual,* UCRL-MA-1333867, Lawrence Livermore National Laboratory, Livermore, CA. The official version is available on the Internet at

http://www.llnl.gov/es_and_h/hsm/llnl_hc.shtml

- Document 3.1, "Safety Analysis Program."
- Document 20.1, "Occupational Radiation Protection."
- Document 20.4, "LLNL Occupational Radiation Protection ALARA Program."
- Document 20.5, "Occupational Radiation Protection: Implementation of 10 CFR 835."

- Document 20.2, "LLNL Radiological Safety Program for Radioactive Materials,"
- ANSI N43.3, "Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up To 10 MeV" (1993).

Other documents (located in the Hazards Control Department) used by the ES&H Team include the

- *Hazards Control Manual.*
- *Radiation Safety Sign Manual.*

Guidance from the following documents has been incorporated into this document wherever feasible:

- U.S. Department of Energy, "Radiation Safety Training Guide," *10 CFR 835 Implementation Guide,* DOE G 441.1–12 (March 1999) (Formerly G–10 CFR 835/ J1–Rev 1).
- U.S. Department of Energy, "External Dosimetry Program Guide," *10 CFR 835 Implementation Guide,* DOE G 441.1–4 (March 1999) (Formerly G–10 CFR 835/ C2–Rev 1).
- U.S. Department of Energy, "Radiation-Generating Devices Guide," *10 CFR 835 Implementation Guide,* DOE G 441.1–5 (April 1999) (Formerly G–10 CFR 835/ C3–Rev 1).
- U.S. Department of Energy, "Posting and Labeling for Radiological Control Guide," *10 CFR 835 Implementation Guide,* DOE G 441.1–10 (May 1999) (Formerly G–10 CFR 835/G1–Rev 1).
- U.S. Department of Energy, "Occupational Radiation Protection Record-Keeping & Reporting Guide," *10 CFR 835 Implementation Guide,* DOE G 441.1–11 (May 1999) (Formerly G–10 CFR 835/ H1–Rev 1).
- ANSI N43.3, "Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up To 10 MeV" (1993).
- ANSI N43.2, "Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment" (1978).
- ANSI N43.1, "Radiological Safety in the Design and Operation of Particle Accelerators" (1978).
- 21 CFR 1020.40, "Cabinet X-Ray Systems" (April 10, 1974).

Appendix A

Acronyms, Terms, and Definitions

The terms and definitions provided in this appendix are specific to their use in this document.

Accelerator	Devices used to accelerate particles to high energies (typically more than 1 MeV). Devices capable of creating an Airborne Radioactivity Area or a High Radiation Area as a result of activation shall meet the applicable requirements of DOE O 420.2A.
Accelerator area	An area where an accelerator is present and radiological controls (e.g., GERT training and dosimeters) are required. The "Accelerator Area" may or may not include the control room.
ALARA	As low as reasonably achievable.
ASE	Accelerator Safety Envelope.
Beam ports	Openings in a radiation-source housing through which radiation is allowed to pass. Collimators, shutters, and filters may be attached to ports to restrict and control the emerging radiation beam.
Controlled area	Any area where access is managed to protect individuals from exposure to radiation or radioactive material.
DUS	Donation, Utilization, and Sales Group.
Enclosed beam	All possible x-ray beam paths are fully contained in a chamber, coupled chambers, or other beam-path-confinement devices to prevent any part of the body from intercepting the beam during normal operations. Normal access to the beam path, such as a sample chamber door, shall be interlocked with the high voltage of the x-ray tube or the shutter for the beam to be considered "enclosed." An open-beam device placed in an interlocked enclosure is considered an "enclosed beam" unless there are provisions for routine bypassing of the interlocks (e.g., for beam alignment).

Entrance or access point	Any location through which an individual could gain access to an area controlled for the purpose of radiation protection. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.
Exclusion area	Any area where a person could receive an effective dose equivalent >5 rem in one hour at 1 m from the source under normal operating conditions.
Fail-safe	A design feature built into the system or its components that causes the system to return to a safe condition if a key component malfunctions in its most likely failure mode(s). (**Note**: If a fail-safe design is not possible or cost effective, the system and its component should be designed to prevent a single failure from placing the system in an unsafe condition.)
Field radiography	Nonroutine radiographic operations in an area or facility that does not have the requisite engineered controls.
High Radiation Area	Any area, accessible to personnel, where radiation levels could result in an individual receiving an effective dose equivalent in excess of 0.1 rem in one hour at 30 cm from the radiation source or from any surface that the radiation penetrates. (**Note**: Dose rates in excess of 500 rads/h are Very High Radiation Areas.)
Incidental radiation-generating device	A device that emits or produces x-rays during normal operation, and the radiation is an unwanted by-product of the device's intended purpose. Examples of such devices include scanning electron microscopes, electron pulse generators, and electron beam welders.
Intentional radiation-generating device	A device in which particles undergo acceleration in a vacuum to produce x-rays for a particular application. Examples are medical devices, flash x–ray systems, x-ray diffraction and fluorescence analysis equipment, klystrons, laser irradiators, and accelerators.
Interlock	A device that precludes access to an area of radiation hazard by either preventing entry or by automatically shutting down the RGD.

Nonroutine operations	Operations that last less than 2 weeks or are conducted less than six times each year.
Open beam	An x-ray beam that is not fully contained within a chamber, coupled chambers, or other beam-path-confinement devices (e.g., shutters), or where there are no physical barriers between an individual and the radiation beam.
Primary beam	Radiation generated from an evacuated x-ray tube that has not been diffracted.
Radiation Area	Any area accessible to individuals where radiation levels could result in an individual receiving a deep dose equivalent exceeding 0.005 rem in one hour at 30 cm from the source or from any surface that the radiation penetrates. (**Note**: Dose rates in excess of 0.1 rem/h are High Radiation Areas.)
Radiation-generating device (RGD)	A device (including accelerators) that generates ionizing radiation either incidentally or intentionally.
RGD	See "Radiation-generating device."
RGD operator	A person who has met the training requirements and is authorized to operate the RGD.
RGD safety officer	A health physicist within the Hazards Control Department who is responsible for providing technical guidance on safety issues related to RGDs and coordinating the overall RGD safety program for LLNL.
RPP	Radiation Protection Program.
Safety plan	A management-approved safety document that describes the hazards and the applicable controls for a particular work activity.
Secondary beam	Radiation that has been diffracted from a primary beam or is generated by fluorescence.
Shall	A mandatory requirement. Exemptions from contractual and regulatory requirements are obtained through the process described in Document 2.3, "LLNL Exemption Process," in the *ES&H Manual*).

Should	A recommended practice. Can also indicate a desirable or best-management practice. Written justification for declining to implement a "should" statement is not required.
Very High Radiation Area	Any area, accessible to individuals, where radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads in one hour at 1 m from the source or from any surface that the radiation penetrates.
Whole body	For the purposes of external exposure, any exposure to the head, trunk (including male gonads), arms (above and including the elbow), or legs (above and including the knee).

Appendix B

Summary of RGD Radiation Safety Requirements

RGD Compliance Item	Further Explanation	Class			
		I	II	III	IV
RGD Characterization/Radiological Safety Evaluation	Initially and upon change	X	X	X	X
Inventory- Class I, II: annually; Class III, IV: semiannually	A verbal/e-mail inventory may be substituted for Class I devices	X	X	X	X
I. Posting and Labeling					
Unique RGD No.	—	X	X	X	X
CAUTION X-Ray Area or CAUTION Accelerator Area	On doors entering rooms with RGDs		X	X	X
CAUTION or DANGER Radiation, High, or Very High Radiation Area	At access points to the radiation area		X	X	X
CAUTION RGD Approved Operating Parameters	On control console	O	X	X	X
Class I RGD Guidance Posting	Guidance posted near RGD	X			
CAUTION RGD label	On tube housing		(X)	(X)	(X)
Last Survey Date/Next Due sticker	On control console	O	X	X	X
II. Interlocks, Warning Indicators					
Interlocks					
Interlock bypass keys are controlled when not in use	Exceptions documented in a safety plan	X	X	X	X
Interlocks are operational (if present)		X	X	X	X
Enclosures of fail-safe design			X	X	X
Flash x-ray interlocked during charging	To prevent entry during charging		X	X	
Emergency shutdown switch	Enclosures that can be occupied			(X)	X
Written interlock test procedures	—		X	X	X
Interlock bypass authorized in safety plan	—		X	X	X
Master key required to access exclusion areas	—				X
Redundant interlocks on access doors to exclusion areas	—				X
Hazard-safe switches at entrances to exclusion areas	—				X
Key-lock watchman stations or run-safe boxes within the exclusion area	—				X
Manual reset requirements for interlocks	—				X
Warning Indicators-Lights					
If warning lights are installed, do not modify	—	X			
Fail-safe warning lights near source	ON, when x-rays are generated or when the machine is being charged. Optional for e-beam devices		X	X	(X)
"X-Ray On" or charging status light	Located near console		X	X	
"Shutter Open" lights near shutter	"Shutter Open" lights should be present		X	X	
Lights dimmed prior to operation	In large exclusion areas				(X)
Rotating magenta lights	At High/Very High Radiation Areas entrances during operation		(X)	(X)	X
Warning Indicators—Announcements					
Voice announcement to vacate	Audible in large exclusion areas				X

X denotes "applicable", (X) denotes "as applicable", O denotes " Optional"

RGD Compliance Item	Further Explanation	Class			
		I	II	III	IV
Warning Indicators—Alarms					
X-ray monitor or safety box, or equivalent fixed detector	Adjacent to port if it will enhance safety		(X)	X	
RAM system with remote readout	Visible and audible alarms				(X)
Alarms sounds with radiation generation/evacuation	Chimes/intermittent (pulsating) klaxon horn				X
III. Shielding & Radiological Safety Survey					
Shielding					
Enclosed Beam Operations					
Dose rate <0.5 mrem/h at 5 cm	Or a dose rate <0.1 rem/y	X			
Dose rate <0.5 mrem/h at 30 cm	—		X	X	
Designed so dose in occupied areas is <0.5 rem/y	—		X	X	X
Beams >0.1 R/h fully enclosed, if feasible	—		X	X	X
Beam ports covered when not in use	—		X	X	
Open Beam Operations					
Visible, posted barrier at 5 mrem/h, 100 mrem/h, and >500 rads/h	—		X	X	X
Constant surveillance and no operator within visible barrier	—		X	X	X
Radiological Safety Survey					
"Not Operational" devices, Class I, II: yearly; Class III, IV: semiannually	May be reduced to a verbal/e-mail inventory for Class I devices	(X)	X	X	X
IV. Documentation					
Integration Work Sheet (IWS)	Authorize RGD use. For maintenance and repair not covered under a safety plan (including interlock bypass). For access to Radiation Areas or High Radiation Areas.	X	X	X	X
RGD logbook	Characterization, surveys, interlock test, and maintenance log. Use log for Class IV RGDs	(X)	X	X	X
Safety plan (OSP or FSP)	To document deviations from the requirements in this document and for interlock bypass operations. (For maintenance and repair, see below)	X	X	X	X
Safety Assessment Document, Accelerator Readiness Reviews	Accelerators capable of accelerating particles to >10 MeV				X
V. Training					
Hazard Information Sheet	Posted at RGD or included in safety plan	X			
Course HS6070 or HS6071, or equivalent	—		X	X	(X)
Course HS6911	—				X
VI. Other Requirements					
Dosimeters					
Whole-body dosimeters	—	X	X	X	X
Extremity dosimeters	As specified by the health physicist		(X)	(X)	(X)
Supplemental dosimeters	Access to High Radiation Areas		(X)	(X)	(X)
Portable Survey Meter	Available at work location and entrances to exclusion areas		X	X	X

X denotes "applicable", (X) denotes "as applicable", O denotes " Optional"